The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #43439

Evaluating the Impact of Additional Examples and Explanation on Student Outcomes in a Free Online Python Course

Mr. Timothy James, Purdue University

Timothy James is an instructor at the University of Pittsburgh Computer Science department, as well as a Doctor of Technology student at Purdue University. Previously, Tim has spent some time in a variety of industries including Internet consulting, finance, defense contracting, aviation maintenance, telecommunications, capital markets, and sandwich artistry. Timothy hopes to continue actively engaging the community in technical training and CS education efforts.

Dr. Alejandra J. Magana, Purdue University

Alejandra J. Magana, Ph.D., is the W.C. Furnas Professor in Enterprise Excellence in the Department of Computer and Information Technology and Professor of Engineering Education at Purdue University.

Evaluating the Impact of Additional Examples and Explanation on Student Outcomes in a Free Online Python Course

Abstract

Helping students to learn a new programming language in a voluntary online course can be time consuming and difficult. Students in such a noncredit course face many challenges in learning; the content must keep their attention, and these students also need to quickly achieve competency in analysis, evaluation, and application of the concepts. As explanation and examples can help in student understanding, the amount of explanation and the number of examples to support these concepts may be a factor in successful learning.

Colaboratory (typically called "Colab") is a free software-as-a-service product provided by Google. It can be quickly accessed through a browser, allowing users to create, modify, and execute Jupyter Notebooks. This environment removes many setup and configuration obstacles for students, and can be used to deliver interactive instructional activities. Jupyter Notebooks can intersperse instruction and explanation with modifiable, executable Python code. These features make it an excellent environment for students to study, learn, experiment, and write their own code, which can be executed through the browser. Students can see the results of running their code almost instantly.

In 2023, the authors taught an online introductory programming course using Colab with similar approaches to two cohorts of students. For both cohorts, students around the world signed up for the course using a public Google Form that was shared on LinkedIn and Twitter. In the first cohort, one group of 174 students received content based on worked examples and try-modify-create pedagogical approaches; the other group of 112 received the same content, but with more explanation and additional examples. A portion of the students were given a choice between shorter lessons and longer lessons in order to compare student preferences to outcomes. The remaining students were randomly assigned to either longer lessons or shorter lessons. Student performance was evaluated through quizzes, assignments, reflection exercises, and a final exam. Other than the inclusion of more explanation and additional examples, the content in the two courses was identical.

In the second cohort, students were randomly assigned to one of three groups. All three groups received ungraded exercises with each lesson in order to evaluate the effect of solutions to these exercises. The first group did not receive solutions to these. The second group received solutions to these exercises, but after a delay of more than 12 hours. The third group received solutions to these exercises immediately.

The purpose of this work is to attempt to understand the effect of additional examples and explanation in an online, free, voluntary, online, asynchronous Python programming course to improve student learning and engagement with the material.

1. Introduction

There is high demand for software developers, and this leads to demand for education related to software development. Unfortunately, it can be difficult to learn these skills – especially programming and how to effectively use a programming language. This can be even more challenging in a free, online environment where students have not paid to participate and are not bound by the threat of failure on their permanent record. Students must be self-directed and well supported in their learning, as they can easily exit the course if they are frustrated or struggle to understand concepts.

Providing additional explanation, clarification, and examples may be a way to improve results, entice higher levels of student participation, and increase the percentage of students who successfully complete course requirements. The purpose of this experimental research is to investigate the effects of lessons extended with additional examples, explanation, and solutions, when compared with shorter lessons that omit these.

2. Background

Examples can be a practical way to demonstrate how to solve problems and how to approach solutions. Morrison et al. found that student performance improved when applying previous knowledge gained from worked examples [1]. Explanations in computer programming can also be effective in improving student performance. Vieira et al. identify the value of explanation in code comments when students are learning programming; using this form of inline explanation can help to reduce the cognitive load imposed when learning programming [2]. The entire scaffolding approach of Use-Modify-Create is based on the use of examples, suggesting that students use examples, modify code, then move on to applying this knowledge to implement their own solutions to new problems [3].

Computational notebooks such as those provided by Colab provide an effective interactive environment that makes it easy to present students with explanations and examples that can be easily modified. This example code may encourage experimentation through modification of existing code [4]. This interspersion of explanation and examples that are directly runnable could help to improve student success; preparing students for solving new problems through explanation and appropriate examples may support student success [5]. Previous work by the authors suggests that using computational notebooks can be effective and can have similar outcomes to an instructor-led course with lectures delivered online [6].

Improving student success is especially important in free, voluntary, online, asynchronous environments as student attrition is high in these environments [7].

3. Experimental Conditions

The purpose of this study was to examine the impact of the amount of content provided to students and how this affected learning outcomes in a free, voluntary, online, asynchronous Python programming course.

There were two phases of this study. The first phase compared the performance of students receiving longer instructional materials to students receiving shorter instructional materials. The second compared the performance of students who did not receive solutions to ungraded challenge exercises to those who received solutions immediately and those who received solutions after some delay.

3.1 Phase 1: Comparing Length of Lessons

The first phase occurred in January 2023. A 20 part course was delivered online via Google Classroom using computational notebooks hosted in Google Colab. The experimental group received lessons that were the same as the control group, but with additional examples and explanation included. Some of these lessons had minimal differences, but others were much longer, containing several additional examples and more detailed explanation.

The lessons are almost entirely code and text, so relative file size can serve as a proxy for the amount of additional examples and explanation. The table below outlines the relative size difference between the computational notebook files used in the longer lessons when compared to the shorter lessons.

Lesson	Topic	Relative File Size of Longer Lesson	Additional Examples in Longer Lesson
1	Introduction	101%	0
2	Arithmetic	124%	3
3	Strings & Data Types	119%	2
4	Booleans & If Statements	125%	2
5	Else and Elif *	429%	2
6	While Loops	121%	3
7	Tuples	122%	3
8	For Loops & Ranges	115%	2
9	Lists	115%	2
10	Strings & Sets	117%	2
11	Dictionaries	141%	2
12	Using Functions **	100%	0
13	Writing Functions	133%	2
14	Functions with Parameters	142%	2

15	Object Methods	104%	0
16	Classes	113%	1
17	Handling Errors	123%	1
18	Modules	122%	1
19	Files	138%	1
20	Problem Solving	124%	1

** The longer lesson for #5 is much larger because it included a diagram.*
*** Lesson #12 focused on explaining standard Python functions, and the difference was negligible.*

An example of the differences in explanation is below, from Lesson #9 on Lists.

Shorter Lessons:

An interesting thing you can do is use `range()` to pre-populate our list.

```
[ ] num_list = list(range(7))
    print(num_list)

    num_list = list(range(0, 30, 5))
    print(num_list)
```

Longer Lessons:

An interesting thing you can do is use `range()` to pre-populate our list.

```
[ ] num_list = list(range(7)) # puts 0, 1, 2, 3, 4, 5, and 6 into a list.
    print(num_list)

    num_list = list(range(0, 30, 5)) # puts 0, 5, 10, 15, 20, and 25 in the list.
    print(num_list)
```

Many of the longer lessons also contained additional examples that are not included in the shorter lessons; one example is below, also from Lesson #9 on Lists.

Example 1 - Collecting Data

The good thing about lists is that we can use them to store things in our code more effectively, since lists can be modified. With tuples we could only use what we wrote in the code; with lists you can store user input, like in this example.

```
user_input = ''
numbers = []

while user_input != 'done':
    user_input = input('Enter a number or enter "done" to end.')
    if user_input == 'done':
        sum = 0
        for number in numbers:
            sum += number
        print('The sum of all those numbers is %s.' % sum)
    else:
        number = float(user_input)
        numbers.append(number)
```

3.2 Phase 2: Comparing Solutions

The second phase occurred in May 2023. As above, this introductory Python programming course was delivered online via Google Classroom using computational notebooks hosted in Google Colab using the longer lessons from Phase 1. This phase focused on the effects of providing solutions to ungraded challenge exercises presented in the course. Ultimately, these additional solutions can further the investigation as they can be seen as additional examples.

There were three student groups: the control group was given ungraded exercises with no solutions (NS for no solutions); the second group was given ungraded exercises, but with solutions released after a delay (DS for delayed solutions); and the third group was given ungraded exercises, but with solutions immediately available (IS for immediate solutions). It is worth noting that the students in the control group (NS) received an identical experience to the longer lesson group in Phase 1.

An example of one of the ungraded challenge exercises from Lesson #9 is below.

Write code below that changes all of the negative values in `some_list` to `1`; print the product (the product is all of the numbers multiplied together) of all of the numbers in the list. Hint: the answer should be 176256.

```
[ ] some_list = [3, -14, -20, 8, 4, -13, -20, 17, 18, 6, -15, 1, -11, -7, -8]
```

The solution for the problem that was provided to both the delayed solutions group (DS) and immediate solutions group (IS) is below.

Write code below that changes all of the negative values in `some_list` to `1`; print the product (the product is all of the numbers multiplied together) of all of the numbers in the list. Hint: the answer should be 176256.

```
some_list = [3, -14, -20, 8, 4, -13, -20, 17, 18, 6, -15, 1, -11, -7, -8]

# if product == 0, then everything multipled by it becomes 0, so start with 1.
product = 1

for i in range(len(some_list)):
    # If it's negative, set it to 1.
    if some_list[i] < 0:
        some_list[i] = 1

    # make sure this line isn't inside of the if statement.
    product *= some_list[i]

print(product)
```

4. Methods

The topical focus, method of delivery, evaluation, and approach to recruiting students was identical for both phases of this study. The content was very similar in all groups - the longer lessons provided in Phase 1 were used for all groups in Phase 2. The ungraded exercises were the same in both phases. All courses were delivered in a 4 week period. In Phase 1, both groups were taught concurrently in January using separate Google Classroom classes. In Phase 2, all three groups were taught concurrently in May using separate Google Classroom classes.

4.1 Participants – Phase 1

In Phase 1, 286 students accepted the invitation to join the course in Google Classroom. Optional student demographic information was collected during the sign up process.

- Gender Demographics: of the 286 students enrolled, 42.11% self-identified as female, 43.86% self-identified as male, and the remaining 14.04% were non-binary or unknown.
- Ethnicity: of the 286 students enrolled, 24.3% self-identified as Asian, 27.46% as Black, 11.62% as Caucasian / White, 12.68% as Hispanic / Latino, with the remaining students unknown or other.
- Employment status: of the 286 students enrolled, 28.77% reported being employed full-time, 8.07% employed part-time, 38.95% were students, 6.32% were unemployed, with the remaining students unknown or other.
- Country of residence: of the 286 students enrolled, 63.4% stated USA, 6.42% stated Ghana, 4.53% stated India, 4.53% stated Nigeria, with no other country represented by 3% or more of the students.

Some students were given the option to request longer lessons or shorter lessons, with others randomly assigned to the longer lesson or shorter lesson group.

- 52 students of the students who chose longer lessons joined the course.
- 60 students of the students who chose shorter lessons joined the course.
- 60 students of the students who were assigned to longer lessons joined the course.
- 114 students of the students who were assigned to shorter lessons joined the course.

For Phase 1, prior to the beginning of the course, students were given a brief, optional pre-test to assess their knowledge. 256 students completed this and the overall average score was 1.55 out of a possible 5. The scores for all groups are similar (+/- 0.34), and the breakdown of these scores is below.

Treatment	**Average Pre-Test Score**
Assigned Longer Lessons	1.45
Assigned Shorter Lessons	1.66
Chose Shorter Lessons	1.35
Chose Longer Lessons	1.69

When comparing all students in the shorter lesson group to all students in the longer lesson group, the scores are even closer (+/- 0.03).

Treatment	Average Pre-Test Score
Long Lessons	1.56
Short Lessons	1.53

4.2 Participants – Phase 2

In Phase 2, 157 students accepted the invitation to join the course in Google Classroom. As in Phase 1, optional student demographic information was collected during the sign up process.

- Gender Demographics: of the 157 students enrolled, 40.57% self-identified as female, 52% self-identified as male, and the remaining non-binary or unknown.
- Ethnicity: of the 157 students enrolled, 32.18% self-identified as Asian, 25.29% as Black, 21.84 % as Caucasian / White, 9.77% as Hispanic / Latino, with the remaining students unknown or other.
- Employment status: of the 157 students enrolled, 38.01% reported being employed full-time, 9.94% employed part-time, 35.67% were students, 9.94 % were unemployed, with the remaining students unknown or other.
- Country of residence: of the 157 students enrolled, 67.5% stated USA, 7.0% stated Nigeria, 5.1% stated India, 3.2% stated Uganda, with no other country represented by 3% or more of the students.

In Phase 2, 55 students who accepted the invitation had been assigned to the group that received no solutions to the challenge exercises; 58 students were assigned to the delayed solutions group; and 62 students were assigned to the immediate solutions group.

No pre-test was administered for Phase 2. The earliest assessment of the students were the results of the first quiz. 88 students submitted the quiz with an overall average of 6.76. The average results for each group are below.

Treatment	Average Quiz 1 Score
Delayed	6.75
No Solutions	6.46
Immediate	7.00

4.3 Data Collection and Data Analysis Methods

Graded material for both phases included 3 quizzes (24%), 3 assignments (30%), 4 reflection exercises (16%), and 1 exam (30%). Quizzes were multiple choice and automatically graded. The same questions were used for all students. Assignments were graded on correctness, clarity of solutions, and ability to follow directions. Students received all available points for submitting the reflection exercises. The final exam consisted of multiple choice questions, short answer questions, and programming problems.

Students were considered to have participated in the course if they submitted any graded item; they were considered to have completed the course if they received 75% or more of the points available.

5. Results

5.1 Participation Rates, Phase 1

All tests for statistical significance were performed using a two-tailed z-test.

Student choice did not convincingly appear to affect participation in the shorter lesson group. 63.33% of the students that chose the option participated, a slightly higher percentage than the participation rate of 59.65% for those who did not make a choice.

Unexpectedly, students that chose longer lessons participated in the course and completed the course at notably lower rates than those who did not make a choice: 42.31% participated in the group that chose longer lessons, while 68.33% participated in the group that was assigned to longer lessons. This difference in participation between students who chose longer lessons and those who were assigned to longer lessons is statistically significant (99% confidence).

Treatment	**Number of Students in Course**	**Number of Students Participating**	**Participation Rate**
Chose Longer Lessons	52	22	42.31%
Assigned Longer Lessons	60	41	68.33%
Chose Shorter Lessons	60	38	63.33%
Assigned Shorter Lessons	114	68	59.65%

Average scores for all students who participated can be used as a further measure of the magnitude of participation. These averages show the lowest participation from the group that was assigned to shorter lessons, but the highest participation from the group that was assigned to longer lessons. This illustrates that students who were assigned to the longer lesson group participated more fully in the course.

Treatment	Average Score
Assigned Longer Lessons	51.22%
Assigned Shorter Lessons	41.13%
Chose Shorter Lessons	43.39%
Chose Longer Lessons	45.39%

Outside of student choice, participation was similar whether students were in the longer lesson or shorter lesson group.

Treatment	Number of Students in Course	Number of Students Participating	Participation Rate
Longer Lessons	112	63	56.25%
Shorter Lessons	174	106	60.92%

The rate of student participation in the course with shorter lessons was higher, but this difference is not statistically significant.

As illustrated in the table below, there is some difference between average scores of students who participated in any way; students who received longer lessons appear to have participated more fully in the course. This demonstrates that more students in the shorter lesson group participated by submitting at least one graded item, but relatively more graded items were submitted by students in the longer lesson group.

Treatment	Average Score
Longer Lessons	49.18%
Shorter Lessons	41.92%

5.2 Completion Rates, Phase 1

Student choice might have made a difference in completion rates, as it appears that students who were assigned to the longer lesson group completed the course at a higher rate than others. This difference is statistically significant (95% confidence). As with participation rates, completion rates are similar between students who chose shorter lessons and those who were assigned to shorter lessons.

Treatment	Number of Students in Course	Number of Students Completing	Completion Rate
Chose Longer lessons	52	6	11.54%
Assigned Longer Lessons	60	16	26.67%
Chose Shorter lessons	60	10	16.67%
Assigned Shorter Lessons	114	18	15.79%

Students in the longer lesson group completed the course at a slightly higher rate than the shorter lesson group, but this result is not statistically significant.

Treatment	Number of Students in Course	Number of Students Completing	Completion Rate
Longer Lessons	112	22	19.64%
Shorter Lessons	174	28	16.09%

5.3 Participation Rates, Phase 2

Participation rates in Phase 2 showed that students receiving immediate solutions (IS) to ungraded challenge exercises participated at higher rates; the difference is statistically significant at 90% confidence when comparing the participation of the group receiving immediate solutions to all others (NS + DS).

Treatment	Number of Students	Number of Students Participating	Participation Rate
Delayed Solutions (DS)	58	28	48.28%
Immediate Solutions (IS)	62	39	62.90%
No Solutions (NS)	55	28	50.91%

When inspecting average scores for all students who participated in any way, the group that received no solutions (NS) is observed to have participated more fully in the course. While more students in the group that received immediate solutions (IS) submitted at least one graded item, the students in the group that received no solutions (NS) submitted relatively more graded items.

Treatment	Average Score
Delayed Solutions (DS)	45.94%
Immediate Solutions (IS)	42.05%
No Solutions (NS)	51.28%

5.4 Completion Rates, Phase 2

Students in the group receiving no solutions (NS) completed the course at the highest rate, with 12 of the 55 students earning 75% or more of the points available. The students receiving immediate solutions (IS) were not far behind, with 12 of 62 earning 75% or more of the points available. The group receiving delayed solutions (DS) was notably behind the others, with only 9 of the 58 students earning 75% or more of the points available.

Treatment	Number of Students	Number of Students Completing	Completion Rate
Delayed Solutions (DS)	58	9	15.52%
Immediate Solutions (IS)	62	12	19.35%
No Solutions (NS)	55	12	21.82%

6. Discussion

Not all of the participation and completion results are significant in this study, but several trends can be observed.

First, it is worth noting that participation and completion rates were similar between the Phase 1 group that received longer lessons and the Phase 2 group that received no solutions (NS). Participation rates were 56.25% and 50.91%, respectively; completion rates were 19.64% and 21.82%. As the course materials for these two groups were identical, it provides an additional point of comparison to the group that received shorter lessons. The completion rate for this group is higher than that of the shorter lesson group, but this result does not meet the minimum threshold for statistical significance.

Treatment	Number of Students	Number of Students Participating	Participation Rate	Number of Students Completing	Completion Rate
Phase 1 Longer Lessons + Phase 2 No Solutions	167	91	54.49%	34	20.36%
Shorter Lessons	174	106	60.92%	28	16.09%

Second, the overall assessment from Phase 1 is that shorter lessons may be correlated with higher participation rates (60.92% for shorter lessons compared to 56.25% for longer lessons). It is possible that overwhelming students with too much material may inhibit participation, but further research is necessary to explore this notion.

Third, the overall assessment from Phase 1 is that longer lessons may be correlated with higher completion rates (19.64% compared to 16.09% for shorter lessons). If the major goal is for students to complete the course, it is also possible that the additional explanation and examples provided in longer lessons provide some assistance or boost to help students in achieving this goal.

Fourth (and somewhat surprisingly), the Phase 2 group that received immediate solutions to ungraded exercises - which can be seen as providing additional examples as part of the lesson and hence more similar to the Phase 1 longer lesson group - had a rate of participation similar to the shorter lesson group from Phase 1. This result may warrant further investigation.

Fifth, the completion rate for the Phase 2 no solutions group (NS) - that did not receive solutions to challenge exercises - was higher than both of the other groups who received solutions. Perhaps this group may have spent more time attempting to complete the challenge exercises, knowing that they would not receive solutions. This may have helped them to understand the content better, but it is difficult to tell from the collected data. Further trials would be required to investigate this hypothesis.

Finally, and counterintuitively, the group completing the course at the highest rate is the group of students assigned to the course with longer lessons – higher than the group that chose longer lessons, and higher than the shorter lesson groups. It is unexpected that there would be a large difference in performance between students who had chosen longer lessons and those that were assigned to longer lessons. Further trials could attempt to confirm this result, and if confirmed, additional studies could provide more explanation for the factors involved.

7. Conclusions and Future Work

Given the small numbers of students in these groups, it is difficult to confidently draw any remarkable conclusions from this study. It does provide some indications that may be interesting for future research (with more controlled groups and additional survey questions). One is that shorter lesson length may encourage higher levels of student participation, but this participation may be more superficial. Another is that more examples and explanation may encourage deeper participation and support students in completing the course. Still another is that providing solutions – whether they are immediate or delayed – may reduce their motivation to complete them on their own and may inhibit their completion of a course. Due to the limited number of students in this study, further research would be required to explore and further support these ideas.

At some point, the number of additional examples and amount of additional explanation may yield diminishing returns. Another area for further investigation may be an attempt at exploring how much is too much and the amount of content that leads to the best results for the highest number of students.

References

[1] B. B. Morrison, L. E. Margulieux, and M. Guzdial, “Subgoals, context, and worked examples in learning computing problem solving,” in *ICER 2015 - Proceedings of the 2015 ACM Conference on International Computing Education Research*, Association for Computing Machinery, Inc, Jul. 2015, pp. 267–268. doi: 10.1145/2787622.2787733.

[2] C. Vieira, A. J. Magana, A. Roy, and M. L. Falk, “Student Explanations in the Context of Computational Science and Engineering Education,” *Cogn Instr*, vol. 37, no. 2, pp. 201–231, Apr. 2019, doi: 10.1080/07370008.2018.1539738.

[3] N. Lytle *et al.*, “Use, modify, create: Comparing computational thinking lesson progressions for STEM classes,” in *Annual Conference on Innovation and Technology in Computer Science Education, ITiCSE*, Association for Computing Machinery, Jul. 2019, pp. 395–401. doi: 10.1145/3304221.3319786.

[4] A. P. Lorandi Medina, G. M. Ortigoza Capetillo, G. H. Saba, M. A. H. Perez, and P. J. Garcia Ramirez, “A Simple Way to Bring Python to the Classrooms,” in *2020 IEEE International Conference on Engineering Veracruz, ICEV 2020*, Institute of Electrical and Electronics Engineers Inc., Oct. 2020. doi: 10.1109/ICEV50249.2020.9289692.

[5] S. E. Chang, “Computer anxiety and perception of task complexity in learning programming-related skills,” *Comput Human Behav*, vol. 21, no. 5, pp. 713–728, Sep. 2005, doi: 10.1016/j.chb.2004.02.021.

[6] T. James and A. Magana, “Evaluating Self-paced Computational Notebooks vs. Instructor-Led Online Lectures for Introductory Computer Programming,” in *2023 ASEE Annual Conference & Exposition Proceedings*, ASEE Conferences, 2023. doi: 10.18260/1-2--43422.

[7] J. Goopio and C. Cheung, “The MOOC dropout phenomenon and retention strategies,” *Journal of Teaching in Travel and Tourism*, vol. 21, no. 2, pp. 177–197, 2021, doi: 10.1080/15313220.2020.1809050.

Appendix

All content for the long lesson course, including assignments, is available here: https://drive.google.com/drive/folders/17w21qKPN-rrATcmOINWziMcqXX7DIb7a?usp=sharing

All content for the brief lesson course is available here: https://drive.google.com/drive/folders/1g_QGIYg0a0FaXvDtk6SXu7A-MjE5ZUlH?usp=sharing – note that the same assignments were used for both courses.

All solutions for the ungraded exercises are available here: https://drive.google.com/drive/folders/1pstZHPUckm7Da02iq5MaAhtA3jsc67rZ?usp=drive_link